ASSESSING THE USE OF ENHANCED SAND FILTER WITH BAMBOO ACTIVED GRANULES FOR TERTIARY TREATMENT OF WASTEWATER EFFLUENT

JOEL PAUL KAYIIRA

M22B32/017

A DISSERTATION SUBMITTED TO THE FACULTY OF ENGINEERING, DESIGN AND TECHNOLOGY IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF BACHELOR OF SCIENCE IN CIVIL AND ENVIRONMENTAL ENGINEERING OF UGANDA CHRISTIAN UNIVERSITY

February, 2026

UGANDA CHRISTIAN UNIVERSITY
A Centre of Excellence in the Heart of Africa

ABSTRACT

Wastewater is a crucial component of the environment. With municipal wastewater that contains organic matter which is harmful to both the environment and the people. High levels of BOD_5, TSS and phosphates present pose a risk on both aquatic life and to the population if not properly handled as these deplete dissolved oxygen therefore need to be treated to NEMA permissible limits of discharge. This study assessed the use of bamboo activated carbon in the tertiary treatment of wastewater effluent from Lubigi stabilization pond putting into consideration of the maturation pond as the wetland 130m downstream, the mean values of BOD_5, TSS and orthophosphates were found to be 100mg/L, 140mg/L and 43mg/L which higher than NEMA discharge limits of 50mg/L, 100mg/L and 5mg/L respectively. The study also evaluated the effectiveness of activated carbon in waste water effluent treatment where its adsorption behavior was described based on different depths of columns. The 30cm depth demonstrated the highest percentage removals of BOD_5 at 80%, TSS at 81% and Orthophosphates at 71% which put the concentrations below the permissible limits.

DECLARATION

I KAYIIRA JOEL, hereby declare that all content of this report is original and has not been submitted anywhere else for whole or partially attainment of any academic qualification.

The results and discussions presented are based on my research, consultations and knowledge gained throughout the course.

Signature …………………………..

Date: …………………………………

APPROVAL

This is to certify the report was done by KAYIIRA JOEL and is ready to be submitted.

Project supervisor,

MR. TAYEBWA RODGERS,

Signature ……………………………………

Date: ……………………………………

ACKNOWLEGEMENT

My sincere appreciation goes to the Almighty who gave me guidance, wisdom, ability and resources in this research journey. I further extend my gratitude to Mr. Tayebwa Rodgers for his endless guidance and bearing with me in this time of the journey, not forgetting Mr. Julius in the lab for his time and assistance and finally my parents and for the encouragement.

Contents

LIST OF TABLES.

LIST OF FIGURES.

LIST OF ABBREVIATIONS

APHA – American Public Health Association

BOD – Biological Oxygen Demand

COD – Chemical Oxygen Demand

mg/L – milligrams / Liter

NEMA – National Environment Management Authority

NWSC – National Water And Sewerage Corporation.

PH – Potential of Hydrogen

SDG – Sustainable Development Goals

TN – Total Nitrogen

TP – Total Phosphates

TSS – Total Soluble Substances

UN – United Nations.

CHAPTER 1. INTRODUCTION

1.1 Background

In 2021, the UN reported that of more than 75,000 bodies of water surveyed across 89 countries, more than 40% were severely polluted. This makes it unsurprising that around the world, 1 in 3 people don't have access to safe drinking water. Predominantly this affects less developed countries such as those in Africa such as Uganda. (Holstein, Feb 2024).

Water stress is the major challenge facing people in the world today especially developing countries which has been caused by climate crisis. (UN Policy, 2019). Water quantity is not the only one issue; the degradation of freshwater quality affects its availability for demanding sectors.

Pollution of these water bodies have been greatly affected by our ever-growing industries. Reporting on industrial wastewater treatment remains limited, with data only reported from 22 countries representing 8 per cent of the global population. In these countries, only 38 per cent of industrial wastewater was reported as treated, and only 27 per cent was safely treated (UN water Progress publication on Wastewater Treatment – 2024).

To minimize and help protect the water sources, great works have been invested in starting from the SDG goals especially SDG 6.3 which has a vision of "By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally"

One of the ways waste-water can be recycled or re-used is by treatment. Waste water treatment is any process that improves the quality of water to make it appropriate for a specific end-use. The most common treatment method used is use of treatment plants which have a combination of filtration, coagulation, and disinfection thus turning waste water into potable water.

However, the other and first form of treating waste water especially on municipal level is the stabilization ponds. WSP also known as an oxidation pond or lagoon, is a shallow, open body of water designed to treat wastewater through natural processes. It utilizes sunlight, bacteria, and algae to break down organic matter and pollutants. WSPs are a cost-effective and relatively simple method for wastewater treatment, particularly in smaller or rural area.

1.2 Problem statement

Lubigi treatment plant is one of the largest treatment plants in Uganda. It has two sectors which help in the proper disposal and treatment of wastes in the Kampala municipal area. It holds above 40% of the wastes in the municipal both sewage and solid wastes brought from the different areas of the city.

The two sectors that handle these wastes at Lubigi are the fecal sludge waste treatment plant and the stabilization ponds having capacity of about 400 m3 for fecal sludge and 5,000 m3 of wastewater daily. (KCCA, 2020). In the ponds, the sewage treatment is natural and disposal of the effluent to the Lubigi swamp as the maturation pond.

This treatment sector has done a tremendous job to treat and remove most of the loads of contaminants in the wastewater before discharge as required by the standards to protect the environment. The ponds removal of pollutants has been effective having efficiencies of above 70% whereas for the facultative ponds above 82% (Bassan, et al., 2022).

However, with the increase in the population of the municipal area, there has been a gradual increase in the nutrient load in the waste water which has led to accumulated sludge near the inlet of the ponds.

Nutrients like BOD5, Total Suspended Substances and phosphates having average values of discharge of 100mg/L, 140mg/L and 43mg/L respectively higher than the permissible limits of 50mg/L, 100mg/L and 5mg/L (NEMA, 1999) respectively. (Secondary data from Treatment Plant). Having such values has led to pollution of the wetland affecting many people and activities in the surrounding area.

Therefore, the purpose of this research is to propose the use of a filter media embedded with activated bamboo as a tertiary treatment of the effluent to help in the reduction of nutrient loads at discharge point.

1.3 Main Objective

To assess the use of a filter media embedded with activated bamboo in tertiary treatment of wastewater effluent.

1.4 Specific objectives

1. To determine the physical – chemical and bacteriological characteristics of wastewater effluent from the stabilization ponds.
2. To determine the percentage removal of pollutants by activated bamboo carbon granules in the media filter.
3. To design a tertiary treatment system using the activated bamboo and in the media filter.

1.5 Scope

It is located in the Upper Lubigi wetland, North - East of Kampala city, Uganda.

Having coordinates of 00°20’48” N, 32°32’28” E. as the wastewater inlet.

And 00°19’56” N, 32°31’34” E as the effluent outlets.

Figure 1: *Aerial view of Lubigi treatment plant*

1.6 JUSTIFICATION

Bamboo is an aggressive spreading plant in the grass family. It is prized and well known for its rapid growth and versatility as a renewable resource.

Bamboo has a high cellulose content of 40 to 50% which makes it excellent in producing nanomaterials such as cellulose nanocrystals and nanofibers. These high properties of strength, large surface area and sustainable coating.

When activated into a carbon;

- It is boosted to large specific surface area, ranging from hundreds to over 900 m^2/g.
- It possesses a well-developed network of micropores, which increases its capacity to adsorb molecules and particles.
- And confirms a highly porous morphology
- When activated its surface has a charge which attracts pollutants and particles when subjected hence adsorbent property.

CHAPTER 2. LITERATURE REVIEW

2.1 Wastewater

Wastewater is the water that has a composition of organic matter, nutrients, pathogens and chemical contaminants. This is water that has been used and contaminated by agricultural, industrial or domestic activities.

2.1.1 Sources.

Domestic wastewater: This is water that originates after use from household activities such as washing, cooking, cleaning and toilet facilities. This water is categorized into two; black water from toilets and grey water from sinks and laundry.

Agricultural runoff: This is water got from the runoff with a mixture of agricultural contaminants like pesticides and fertilizers which contain mostly high nitrate contents.

Industrial wastewater: This is water that comes from industries. Can be black water, grey water or generally water from the plants containing chemicals, metals and oils. This water s harmful to the environment so has to be treated or follow a regulation for disposal to the environment.

Municipal wastewater: This is water released after usage by homes, businesses and storm runoff into a sewer system of a city. This water contains human waste, food particles, chemicals and pathogens.

In this water; there are major characteristics of the pollutants. i.e.;

- ✓ Nitrogen and phosphorus, these are nutrients that show the levels of discharge from industries and agricultural activities.

- ✓ Chemical oxygen demand and biochemical oxygen demand. These are parameters that go hand in hand and they show the level of decomposition of pollutants in wastewater. BOD shows the levels of oxygen used by microbes while COD shows the levels of DO used in oxidation of chemicals.
- ✓ Heavy metals and Inorganic salts which are indicators of Industrial pollution.
- ✓ pH and electrical conductivity. PH shows the level of acidity or alkalinity in the water while shows the concentration of ions in the water. This water is taken to a treatment facility as it needs to be treated to reduce risks to public health and the environment.

2.1.2 Harmful component of waste water.

Un-treated wastewater as said when exposed to the environment is harmful due to the presence of nutrients in it.

Nutrients found in wastewater include phosphates, nitrates, TSS, Potassium and others like human wastes. These nutrients come from substances like human wastes, food, soaps and detergents.

Phosphate is considered the main cause of eutrophication and has received considerable attention recently.

Phosphates as phosphorous in wastewater exists in majorly three forms: orthophosphate, polyphosphate and organically bound phosphate (Oram, 2009).

Orthophosphates are the reactive forms that are formed through degradation of organic phosphorous and hydrolysis of inorganic polyphosphates (Oram 2009).

The organically bound phosphate is the phosphate that is tied up in plant tissue, solid wastes, or other organic materials, and they become converted to orthophosphate after decomposition (Oram 2009). The rest of the phosphates are got from runoff and leaching from plants that don't utilize it. (Filippelli 2009).

Total Suspended Solids.

Refers to waterborne particles that exceed 2 microns in size. Any particle that is smaller than 2 microns, on the other hand, is considered a total dissolved solid (TDS). The majority of total suspended solids comprise of inorganic materials; however, algae and bacteria may also be considered TSS. (Campbell, 2021).

These are the solid particles that float or "suspend" in water, which can cause turbidity and inhibit plant growth by reducing photosynthesis when present in elevated concentrations.

2.2 Legislation on wastewater.

Wastewater collection and treatment is a very vital component of the environment as it impacts the public health as it has helped in the curbing of diseases spread through polluted water. However, waste discharges from municipal sewage treatment plants into waterbodies is still a concern (Ramseur, 2018).

The clean water act establishes performance levels to be attained by municipal sewage treatment plants in order to prevent the discharge of harmful wastes into surface waters.

2.2.1 International framework.

The United Nations supports the clean water act under its Sustainable Development Goal 6 (SDG 6).

This aims to ensure access to water and sanitation for all by 2030. This goal recognizes the importance of wastewater management as a critical aspect of water resource management and seeks to ensure that water is safely managed and treated (UN, 2015).

Target 6.3: Halve the proportion of untreated wastewater (Aims to reduce the amount of wastewater to be released without treatment.)

: Reduce pollution. (Seeks to lower the overall pollution of water bodies)

: Minimize release of hazardous chemicals and materials. (Focuses on preventing the release of harmful substances into the water system).

Target 6.5: By 2030, integrated water resource management should be fully implemented at all levels of governance. Special attention should be given to fostering corporation among countries that share water resources.

2.2.2 National framework. (UGANDA).

Water Act, Cap 152 is the legal framework for safeguarding and guaranteeing the sustainable use of Uganda’s water resource is provided by this act.

Water resource Management regulations.

The National Water and Sewerage Corporation (NWSC) is tasked with regulating and managing water resources. It is responsible for ensuring that all wastewater discharge activities meet national environmental and safety standards. Inclusive wastewater management.

Water Management Planning regulations.

All regulated entities are expected to create and implement comprehensive water management plans. These plans must include strategies for the proper treatment and disposal of wastewater.

Public Health Act Cap 242.

The main legislative framework for preserving public health in Uganda is provided by this act. In order to prevent pollution and safeguard the public's health, it mandates that every wastewater outflow must adhere to specific health and sanitation requirements.

One of the policy's main goals is public education. It seeks to raise awareness of the significance of appropriate wastewater management through outreach initiatives and awareness campaigns.

This water needs to be treated so as to remove contaminants before releasing to the waterbodies like lakes, ponds and swamps.

2.3 Wastewater treatment facilities or plants.

Engineers, scientists, and financial analysts must utilize principles from a wide range of disciplines: engineering, chemistry, microbiology, geology, architecture, and economics to carry out the responsibilities of designing a wastewater treatment plant.

One of the methods used to treat wastewater is stabilization ponds. In Kampala one of the ponds are located at Lubigi treatment facility.

2.3.1 Lubigi wastewater facility.

This facility has two sections; the fecal sludge section and wastewater stabilization ponds.

For the ponds, there are three ponds i.e., anaerobic pond, facultative pond and maturation pond. These ponds are set in series to each other, thus water flowing from the anerobic through the facultative to the maturation.

Normally; anaerobic ponds are deepest and set out in series to the facultative ponds. They are shallower than the anerobic ponds and then the maturation set out to be shallowest are used in series.

2.3.1.1 Anerobic ponds.

These are the first ponds or initial ponds that help in the breakdown of organisms which use the autotrophs bacteria as the medium to break them down.

These ponds work under the anoxic conditions (without oxygen) and are the deepest of all the ponds. They receive all the wastewater with all its organic load and tasked to reduce it to a great extent such as BOD, TSS, and COD which are a harm to the environment.

These ponds are normally at a depth of 3m to 5m in order to accommodate the anerobic bacteria which uses the anerobic digestion for treatment. This digestion requires certain conditions such as PH < 6.1, and temperatures above 18^oC.

At Lubigi, there are three anaerobic ponds arranged in parallel to each other. These have a total volume of 4640m^3 at dimensions of length (60m) and width (30m).

The ponds work efficiently under two techniques; removal by sedimentation of solids and digestion by bacteria.

2.3.1.2 Facultative ponds

These are the 2nd phase of the WSP connected to the anerobic ponds. They range from 1m to 2m deep with an average detention time of 2 to 3 weeks thus more efficient in bacterial removal.

These ponds are partly aerobic and anerobic in nature. Having these conditions thus having both heterotrophs and autotrophs as the bacteria in charge of breaking down the nutrients. These ponds are divided into two; primary facultative and secondary facultative.

Facultative ponds are designed for BOD removal on the basis of a relatively low surface loading (100 – 400 kg BOD/ha.day) (Kone & Peter, 2010).

It is estimated that about 30% of the influent BOD leaves the primary facultative pond in the form of methane. A high proportion of the BOD that does not leave the pond as methane ends up in algae. This process requires more time, more land area, and possibly 2 -3 weeks hydraulic retention time, rather than 2-3 days in the anaerobic pond.

The pH> 9 is obtained in the pond after some biological processes, which can kill fecal coliform hence reducing the pathogens levels in the pond.

At Lubigi, there are two facultative ponds of total capacity 11530m^3 arranged in parallel. They are of 170m (length), 50m(width) in dimensions.

This sector of the ponds has algae which acts as both a nutrient reduction agent and source of oxygen. The algae intakes carbon dioxide and provides oxygen in the pond. This ensures removal of BOD5 from the waters that enter the pond from the anerobic segment. As most of the BOD is transferred to methane, it doesn't leave the pond but taken in the algae as well.

Wastewater is simultaneously treated with the liquid effluent of the fecal sludge from settling-thickening tanks in WSPs as done at Lubigi treatment facility. However, the addition of the effluent from the fecal sludge thickening tanks should not to exceed 4% (Bassan, et al., 2014) as this can increase ammonia concentration not excluding organic load which cuts the effectiveness of the system (Bassan, et al., 2014).

2.3.1.3 The maturation pond.

Maturation ponds are usually the third of the WSPs in the treatment process. They receive effluent from facultative ponds and their size and number depend on the required bacteriological quality of the final effluent (Quiroga, 2005).

Maturation ponds are usually designed majorly to remove excreted pathogens (WHO, 1987). They also make a significant contribution to nitrogen and phosphorous removal and to a smaller extent achieve removal of BOD (Varon et al., 2004).

The pond geometry influences the sludge sedimentation patterns with them, (Quiroga, 2025) turning the water movement and mass dispersion. The most common shape is rectangular, although there is much variation in the length-to-breadth ratio and it should be 2:1 (Tayler, 2018)

Unlike other maturation ponds which are manmade, for Lubigi treatment plant, the maturation pond is the Lubigi wetland or swamp close to the plant. This is the final pond for the polishing and pathogenic removal. It acts as the bio filter and removes the pathogens that escaped the facultative ponds.

Lubigi is a Kyoga drainage basin wetland located in the north-western part of Kampala. This receives stormwater and polluted water from all over Kampala. The main water inlet is a canalized stream, which receives discharges from the treatment plant of design capacity of 5400m^3/day.

The section of the wetland that receives the initial and direct impacts of effluent from the upstream of the plant is surrounded by in the north-east of Kampala by Hoima, south – west by Sentema with main effluent discharges into Mayanja River finally Kyoga. The wetland is dominated by thick loose peat near the inlet, (Plant manager, 2025) and the thickness of loose peat rapidly decreases downstream till the end.

Given the large surface of the pond, protozoan cysts and helminth eggs are removed, allows for high photosynthetic activity brought by penetration from solar radiation and lastly ultraviolet penetration as a disinfector.

Below is a schematic diagram showing the waste stabilization ponds.

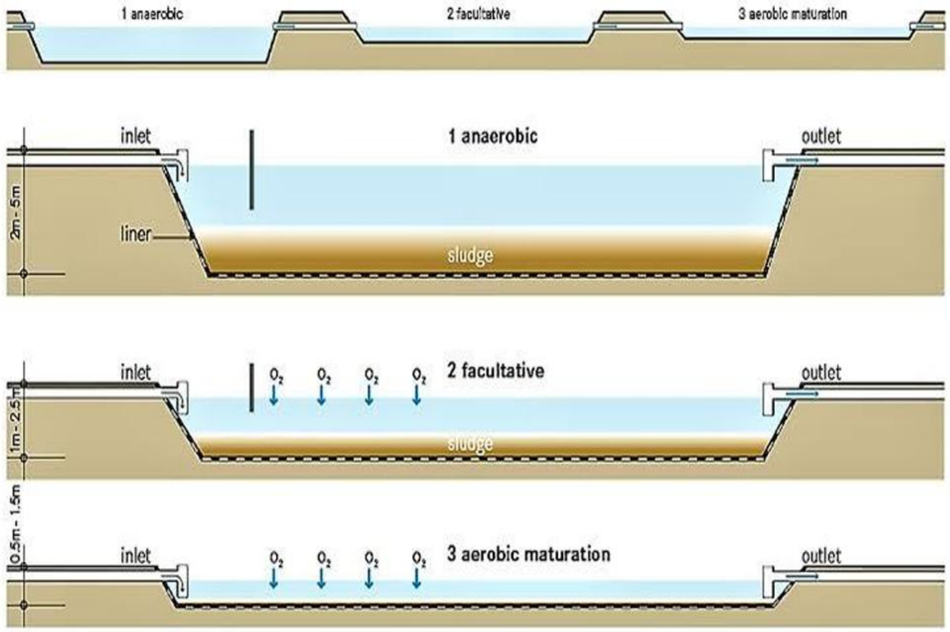


Figure 2: ***Flow of the stabilization ponds*.**

2.4 Tertiary treatment.

Despite the efficiency of the ponds in the removal of most organic pollutants, there are other pollutants in form of inorganics that affect the quality of effluent. In Uganda due agricultural and domestic uses, the most common are nitrogen and phosphorous (Zagklis and Bampos, 2022). Moreover, strict quality criteria need to be met before the treated water can be released to the waters of the environment.

To meet this, several secondary effluent treatment methods have been developed and implemented, typically called tertiary treatment processes.

Below are some of the methods used in tertiary treatment due to their low operational costs, as well as their high efficiency.

2.4.1 Chlorination

This is a commonly used disinfector in water treatment especially in the last stages of treatment. It is a strong oxidizer as it reacts with organic compounds and eliminates them from the water.

This is greatly used in the removal of microorganisms like bacteria, fungi, etc in the water.

It is dosed at different levels or volumes depending on the amount of water and load of pollution in the water being treated. The higher the pollution load and the more of the water, the higher the dosage of chlorine to effectively treat the water as needed.

Figure 3: Chlorination

Methods of chlorination.

Gas chlorination. Chlorine gas in its cylinders dosed in the water.

Hypochlorite. Chlorine is added in the form of liquid (bleaching agent).

Super chlorination.

More chlorine than necessary is added to ensure effective oxidation of contaminants like iron and manganese, after which the excess is removed.

2.4.2 Ultraviolet radiation.

The radiation treatment operates as the radiation wavelength reaches the bacterial cells, it penetrates their outer layer and gets absorbed by the DNA molecules (PureTech, 2025).

This creates a kink in the bacterial DNA which later halts processes like protein synthesis. This also acts as a disinfector.

2.4.3 Membrane filtration: This technique uses semi-permeable membranes to separate contaminants from liquids or gases.

This works when a fluid is forced through a semi permeable membrane under pressure.

The membrane then allows particles smaller than its pore size to pass through while larger particles contained. This is one of the ways to purify liquids, and remove harmful organisms.

Types of membrane filtration.

Microfiltration

Nanofiltration

Reverse osmosis

Ultrafiltration.

2.4.4 Constructed wetlands (CWs):

These are engineered systems that have been designed and constructed to utilize the natural processes involving wetland vegetation, soils, and the associated microbial assemblages to assist in treating wastewaters.

Types of CWs.

Free water surface

This is a series of flooded planted channels or basins. As water slowly flows through the wetland, particles settle, pathogens are destroyed, and organisms and plants utilize the nutrients.

water flows above ground and plants are rooted in the sediment layer at the base of the basin or floating in the water. As the water slowly flows through the wetland, simultaneous physical, chemical and biological processes filter solids, degrade organics and remove nutrients from the wastewater. The channel or basin is lined with an impermeable barrier (clay or geo-textile) covered with rocks, gravel and soil and planted with native vegetation (e.g., cattails, reeds and/or rushes). The wetland is flooded with wastewater to a depth of 10 to 45 cm above ground level. (HOFFMANN et al. 2010).

Subsurface Horizontal Wetland: A horizontal subsurface flow constructed wetland is a large gravel and sand-filled basin that is planted with wetland vegetation. As wastewater flows horizontally through the basin, the filter material filters out particles and microorganisms degrade the organics.

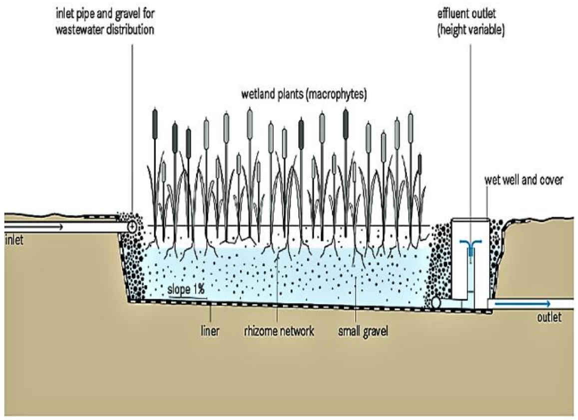


Figure 4: Subsurface Horizontal wetland

In this, the water moves parallel to the surface. The vegetation transfers a small amount of oxygen to the root zone so that aerobic bacteria can colonize the area and degrade organics as well.

The plant roots play an important role in maintaining the permeability of the filter.

For the vertical subsurface flow, wastewater is pumped into the wetland and flows vertically downward through the media.

The other systems include; hybrid systems, and floating treatment wetlands.

2.4.5 Filtration:

This is a wastewater purification stage.

At this stage, fine suspended solids, nutrients like nitrogen and phosphorous, and other contaminants are removed to produce higher quality water.

This is also known as effluent polishing.

Methods of filtration.

Media filtration: Layers of materials such as sand, gravel, etc. are set together to physically trap particles.

Cloth filters: A multi fiber fabric is used to capture suspended solids, bacteria and micro-plastics thus allowing clean water to pass through (Tchobanoglou et. al, 2003).

They operate on principles of depth filtration, surface filtration, and in some instances, biological treatment.

Figure 5: ***Advanced cloth filter***

dvanced Methods: More advanced processes are used such as carbon adsorption, membrane bioreactors and reverse osmosis.

2.4.6 Carbon Adsorption.

Adsorption is a surface phenomenon and it involves the deposition of atoms or molecules on the surface of a material. The accumulation of pollutants in the wastewater onto the surface of the adsorbent (Goldberg 2013). Activated carbon is used to remove pollutants from water through a process where contaminants stick to the carbon's porous surface. Adsorption is the most promising method that employs a wide range of materials (adsorbents) with high efficiency in removing pollutants from wastewater.

The suitability of an adsorbent in pollutant removal depends on the properties such as high selectivity, high adsorption capacity, low cost, high stability, and long life (Ghaedi 2021).

The activated carbon is placed in a filter layer or its powder used directly into the water thus adsorbing the nutrients depending on the material used to form activated carbon. Activated carbon is prepared in different forms based on the application such as powdered activated carbon, granular activated carbon, and activated carbon fibers.

The generation of porosity, surface area, and functional groups depend on the synthesis and activation methods as well as the sources of activated carbon.

Most adsorbents, especially nano-adsorbents, are recyclable thereby making the adsorbed pollutants easily removed from the surface of the nano-adsorbents (Nnaji et al. 2018). Methods for obtaining activated carbon.

Carbonization.

Activated carbon is got from carbonization. This is converting organic materials like waste plants and dead animals into carbon. Carbonizing is a pyrolytic process where different processes occur at once i.e., dehydrogenation, condensation and isomerization.

This process differs from coalification as it occurs much faster, due to its reaction rate being faster by many orders of magnitude (Anderson, 2023).

This is heating the biomass in a limited supply of oxygen to drive off water and volatile compounds, leaving behind a carbon-rich residue.

There are several methods or technologies used to carbonize from local methods to machine or industrialized methods. In all these, the process is the same just the equipment and time varies;

Local method; The material used is burnt in a dug hole, covered for a period of 24hrs so as to provide an oxygen free environment and great volumes of the carbon obtained.

Basic method: The material is burnt in a drum or a drum like container with a cover so as to provide the oxygen free environment. This gives the carbon in a short period of time (3 to 6hrs) though provides few volumes of the carbon due to container size.

Industrialized method. The material is burnt in a kiln at high and measured temperatures. This provides large volumes in a short period of time.

Activation.

This is where the carbon is modified to acquire the large surface and porous nature for proper adsorption.

There are typically two methods of activation; physical and chemical.

Physical: The material after carbonization is exposed to oxidizing agents like carbon dioxide or steam at high temperatures (400^{o}C).

Chemical: The material after carbonization is impregnated with chemicals like phosphoric acid or potassium hydroxide and then exposed to low temperatures of (250^{o}C to 300^{o}C).

Bamboo activated carbon

This is obtained from carbonization of bamboo stems or bamboo waste. It creates and has extraordinary properties in this form such as large surface area, high conductivity and adsorption capacity (Rout et. al, 2022).

When activated, it generates multiple adsorption sites due to the porous nature it formulates. At this stage, due to high conductivity, it attracts particles such as pollutants in water due to the attractive force on the surface.

CHAPTER 3: METHODOLOGY

This chapter determines the methods and testing that will be incorporated during the research.

3.1 To find out the physical – chemical and bacteriological characteristics in the wastewater stabilization ponds.

- Collection of preliminary data from the plant manager on their weekly tests.
- Organization and analysis of data collected using excel spreadsheet software.
- Formulation of graphs for the different parameters above the permissible limits of discharge as per NEMA.

3.2 To determine the percentage removal of pollutants using activated bamboo in a media filter.

3.2.1 Testing the raw water for the parameters.

Sample collection.

- ✓ Collection of two samples from outlet of facultative pond.
- ✓ Mixture of samples to obtain a composite sample.
- ✓ Placed in a cooler box under 4^0C using Ice.

3.2.1.1 Total Suspended Solid (APHA 2540C)

Equipment; Spectrophotometer (DR 3900), beaker, sample cell and measuring cylinder.

- ✓ Shake the sample vigorously to attain complete mixture
- ✓ Take 25ml of distilled water (Blank) and 25ml of sample in different sample cell.

- ✓ Zero the spectrophotometer with the blank (calibration).
- ✓ Read the concentration in mg/L of the sample.
- ✓ Click on 630 as the wavelength for TSS.
- ✓ Record machine reading directly.
- ✓ Repeat for triplicate values.

3.2.1.2 Ortho-phosphate (APHA 4500E).

Sample collected and tested within 24hrs.

Preparation of lab and wearing of protective gear.

Equipment; Sulphric acid, potassium antimony tartrate solution, ammonium Molybdate solution, Ascorbic acid, stock phosphate solution and standard phosphate solution. (mixed reagents let to settle for 15mins)

- ✓ Filter the water sample in 0.45µm What man filter paper.
- ✓ Take 25ml of diluted filtered sample.
- ✓ Prepare blank of (25ml) and phosphate standard by taking 25ml of known standard concentration. Treat both as samples.
- ✓ Add 3ml of mixed reagent and mix well.
- ✓ Add 1ml of ascorbic acid to each sample and mix well.
- ✓ Let it settle for 20mins for blue color development.
- ✓ Measure and record the value from the spectrophotometer (DR3900) at 880nm wavelength.

3.2.1.3 Biological Oxygen Demand. (APHA 5210B).

Equipment: Incubation bottles, pipette, Air incubator, DO meter.

Procedure.

- ✓ The dilution water was prepared by adding water to a bottle and saturating it with dissolved oxygen by aerating with organic free filtered air, and this was followed by the addition of the nutrient stock solution of phosphate buffer, calcium chloride, Ferric chloride, and magnesium sulfate 1ml each per a liter of saturated water.
- ✓ The nutrients are added to ensure that the microorganisms have sufficient inorganic nutrients while decomposing the organic matter and the nutrients do not contribute to the consumption of dissolved oxygen in the waste water sample solution.
- ✓ 5ml of the sample were added to a 300ml beaker and the dilution water added up to the 300ml mark and stirred.
- ✓ The initial DO of the samples was measured using an already calibrated DO meter. The samples were then added to the 300ml BOD bottles and 22 filled to the brim and closed with a stopper to prevent the penetration of oxygen.
- ✓ The BOD bottles were amber in color to prevent light penetration which promotes photosynthesis.
- ✓ The BOD bottles are then placed in an incubator at a temperature of 20°C for 5 days. The final dissolved oxygen of the samples was then obtained.
- ✓ The initial dissolved oxygen (DOi) was subtracted from the final dissolved oxygen (DOf) and multiplied by the dilution factor which is the ratio of the volume of the BOD bottle to the sample volume.
- ✓ The biochemical oxygen demand is then obtained from; $BOD = (DOi - DOf) * P$

3.2.2 Bamboo carbonization.

Collection of bamboo waste from manufacture artifacts company.

Figure 6: ***Cut logs of bamboo***

Chop the bamboo into small pieces for carbonization.

Pieces placed in a drum and burnt under no oxygen content for effective carbonization (anoxic) to prevent excessive burning for 3 to 4hours.

Figure 7: Carbonization of the bamboo

Continuous cooling of the drum by locally pouring of water at surface to preventing over burning.

The carbon is then activated with steam at high temperatures using a kiln.

The carbon is then removed and cooled to about 40^0C.

Figure 8: Carbonized bamboo

It is then crashed into sizes required for the filter.

The granules are then washed carefully and dried to properly prepare them.

CHAPTER 4: RESULTS AND DISCUSSION.

4.1: Determining the physical- chemical and bacteriological characteristics of the raw water.

The preliminary tests carried out on the wastewater effluent from the facultative ponds of Lubigi treatment facility as it is the final of the ponds to the swamp and then other tests 130m downstream of the swamp.

This was to find out the dilution effect of the swamp on the wastewater effluent discharged to the swamp.

The parameters were chosen based on the nutrient load and effects of the parameters on the environment.

Secondary data was used for these results as these parameters are monitored on a weekly basis at the treatment plant.

Table 1 ***latest test results***

Parameters	Units	Final Effluent results	Downstream results	NEMA standards
Dissolved Oxygen (DO)	mg/L	3.54	0.04	-
PH		7.84	7.88	6.0 – 8.0
Electrical conductivity (EC)	µs/cm	1601.25	663.5	-

Temperature	(˚C)	25.1	25.4	20 - 350
TSS	mg/L	141	128	100
BOD	mg/L	108	90.75	50
COD	mg/L	97.5	93.75	100
Phosphate (Ortho)	mg/L	41.97	15.3	5.0

As shown in table above; most the parameters fall under the NEMA permissible limits for wastewater discharge to the environment or wetlands. Though three parameters of BOD5, TSS and Phosphates(soluble) go above standards.

4.1.1 BOD

BOD is considered as a parameter used as an index of the degree of organic pollution in water.

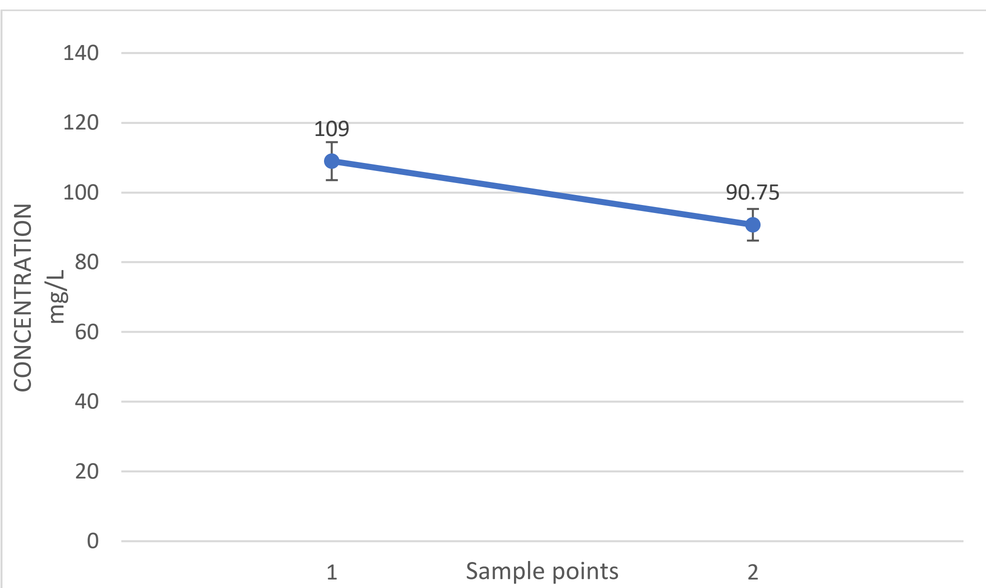


Figure 9: ***Effluent at discharge and 130m downstream.***

As the wastewater enters the pond, Uganda is a developing country with low water usage in general (20 to 40L per person) which increases the waste to water ratio in wastewater thus having less dilution effect of nutrients which has increase the BOD as the microbe's decomposition is increased.

BOD value is 109mg/L which is above 90.75mg/L as per Nema discharge standards. Even with the dilution effect in the wetland 130m away from discharge point, it is 90mg/L which is above 50mg/L of NEMA.

As the wastewater moves downstream, it mixes with cleaner water thus reducing on the concentration of organic pollutants which reduces on the BOD.

As the wastewater moves physically in the wetland, there is re-aeration from the atmosphere thus replenishing DO that was utilized by the microbes.

4.1.2 TSS

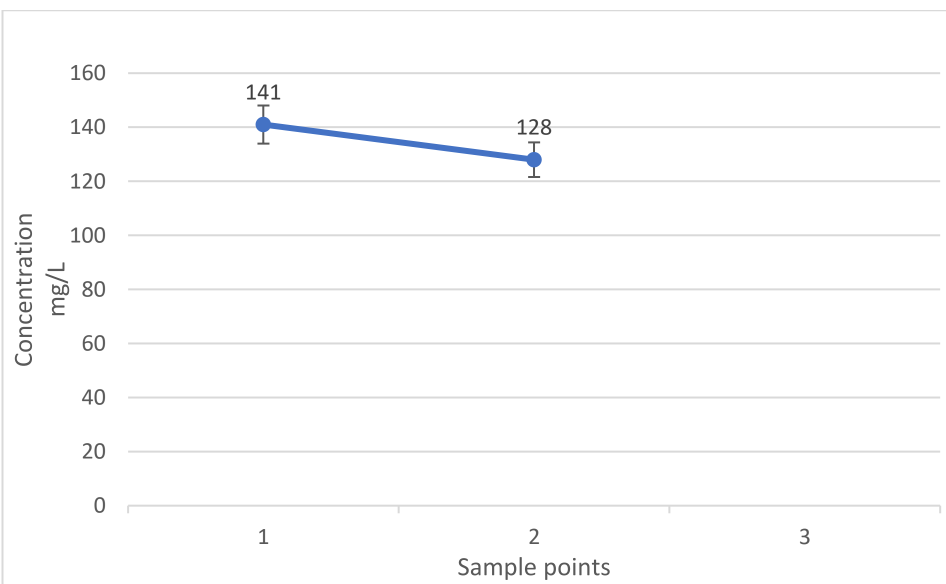


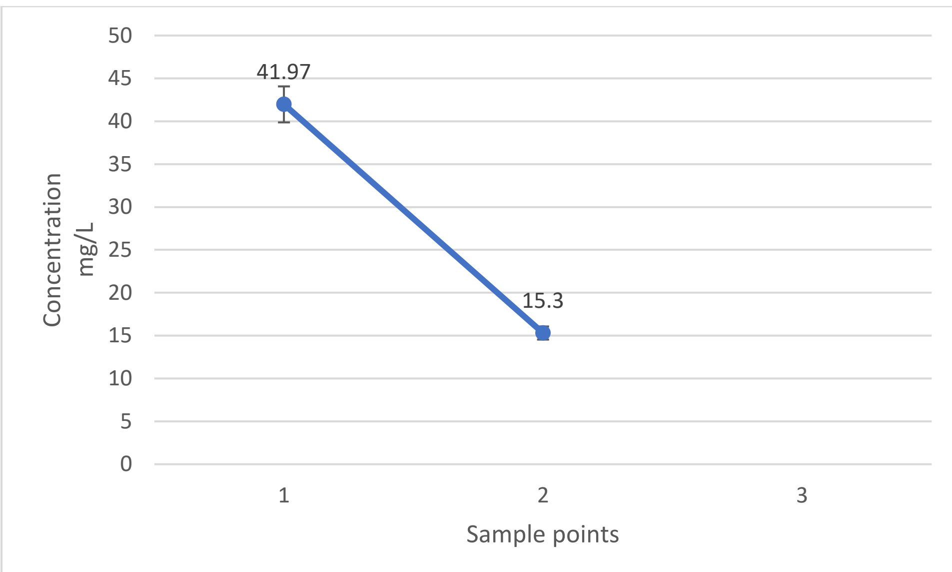
Figure 10: Effluent at discharge and 130m downstream

TSS value at 141mg/L and 128mg/L above the standards of 100mg/L even with the dilution effect downstream due to the reduction in retention time to settle out the particles within the ponds.

As the wastewater is discharged, the wetland gives it a platform in which settles out the particles thus actin like a sedimentation tank.

4.1.3 Orthophosphate

11: Effluent discharge and 130m downstream



The Orthophosphates concentration at 41.9mg/L at the discharge point and 15.3mg/L with the dilution effect downstream which is above the 5mg/L of NEMA discharge.

As the wastewater mixes with the cleaner water, there is dilution which reduces on the orthophosphate concentration. It also gives the microbes that intake the orthophosphates time to luxury consume thus reduction on the concentration.

4.2 Determination of percentage removal by carbon granules in tertiary treatment.

Carbon granules were embedded in a filter media of sand(400mm) depth and gravel as bed of 120mm depth.

The granules depths were varied from 8cm to 30cm and percentage removal of pollutants was recorded.

Using; $\frac{Initial\ value - final\ value}{Initial\ value} * 100$

A 2L Bottle of water was used to pour wastewater in the designed filter embedded with the activated carbon and the following were obtained with their thickness (size).

4.2.1 BOD

Table 2: BOD percentage reduction with depth of carbon

Parameter	Unit	Filter A1	Filter B1	Filter A	Filter B
Initial BOD	mg/L	100	100	85	85
Carbon length	cm	8	12	20	30
Final BOD	mg/L	68	66	53.5	51
Percentage reduction	%	32	34	37	40

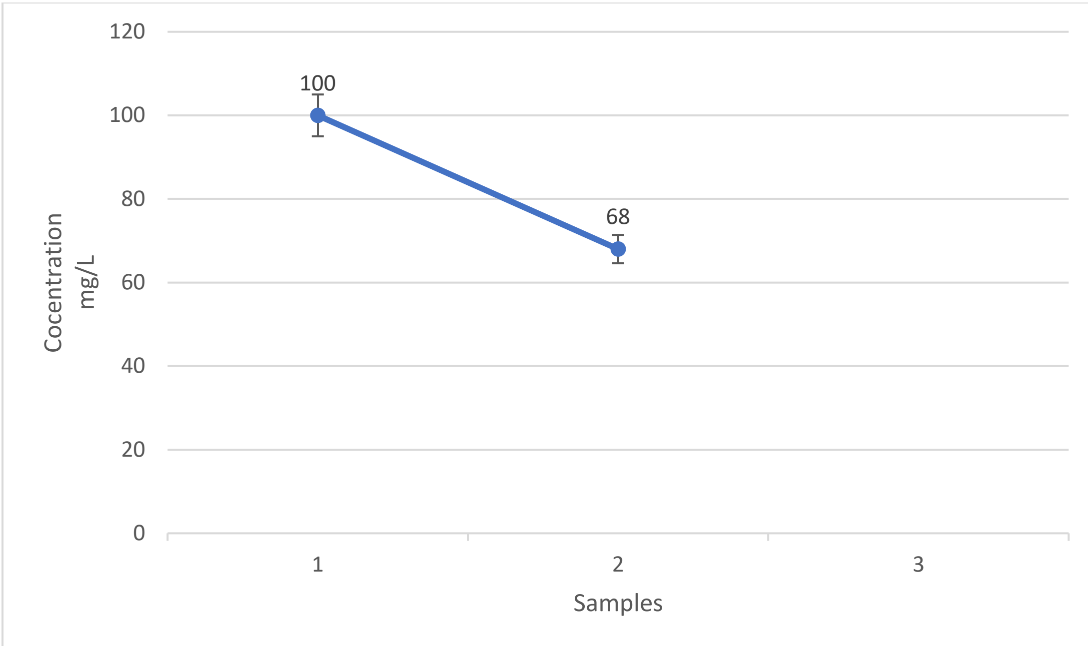


Figure 12: ***Filter A1 at 8cm depth of carbon***

The BOD concentration reduced from 100mg/L to 68mg/L with aid of a filter that has 8cm carbon depth.

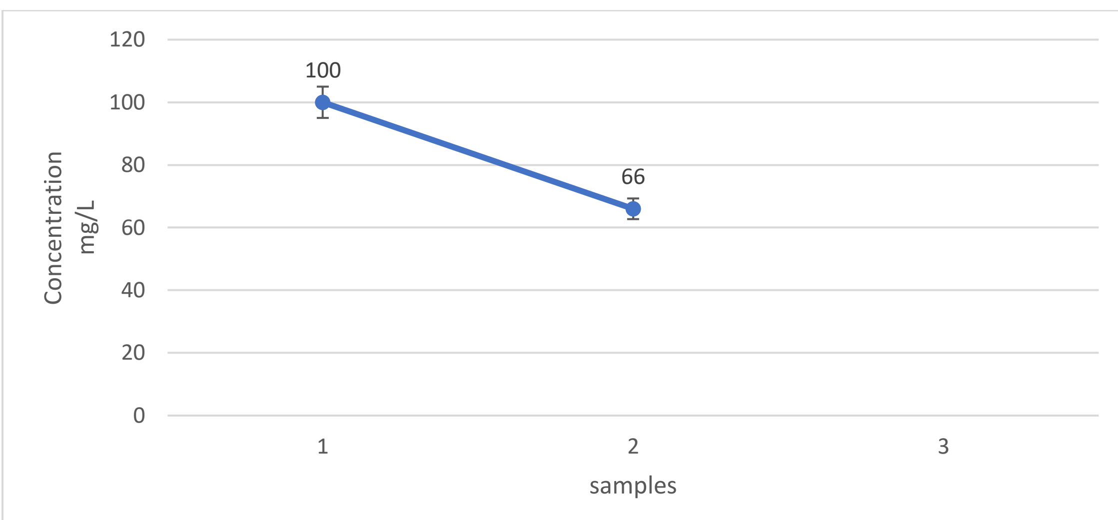


Figure 13: *Filter B at 12cm depth of carbon*

The concentration dropped from 100mg/L to 66mg/L with a filter of 12cm depth of carbon.

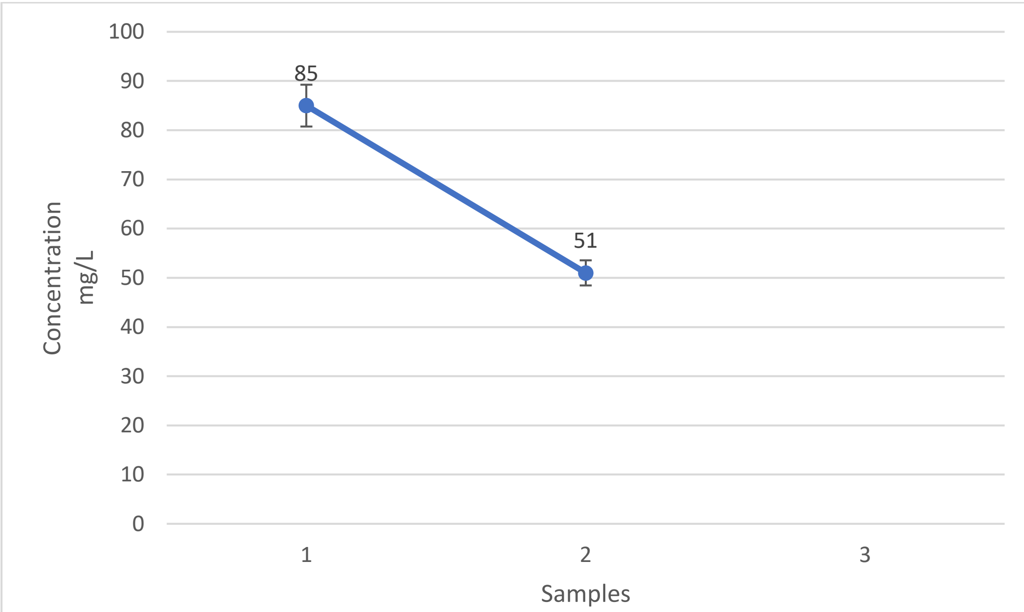


Figure 14: ***Filter B at 30cm depth of carbon.***

The concentration of BOD is reduced from 85mg/L to 51mg/L at column depth of 30cm. This is due to the increase in the depth of carbon, which gives it enough contact time for adsorption of pollutants in the water. At this depth, there are more sites and pores for pollutant depositions.

4.2.2 TSS.

Table 3: TSS percentage reduction with depth of carbon

Parameter	Units	Filter A1	Filter B1	Filter A	Filter B
Initial TSS	mg/L	138	138	110	110
Carbon length	cm	8	12	20	30
Final TSS	mg/L	126	84	44	20
Percentage reduction.	%	8.7	39	60	81

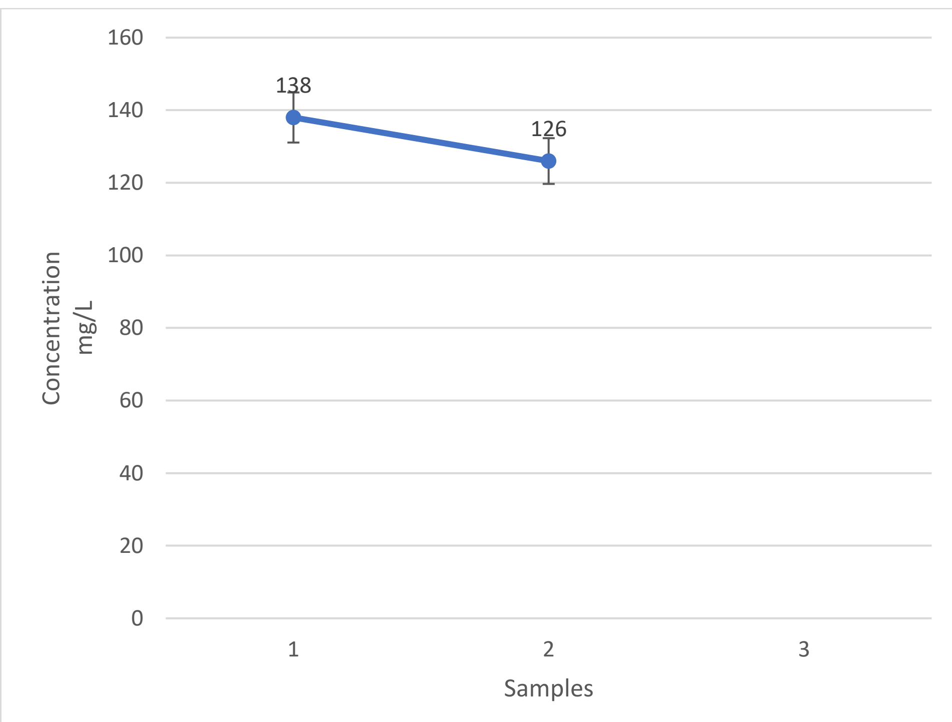


Figure 15: Carbon length at 8cm

At 8cm depth, the TSS value reduces from 138mg/L to 126mg/L. This is due to the availability of the carbon that has activated sites that attract some of the particles in the water. At this depth, there is a low 8.7% reduction due to the limited sites in the column depth.

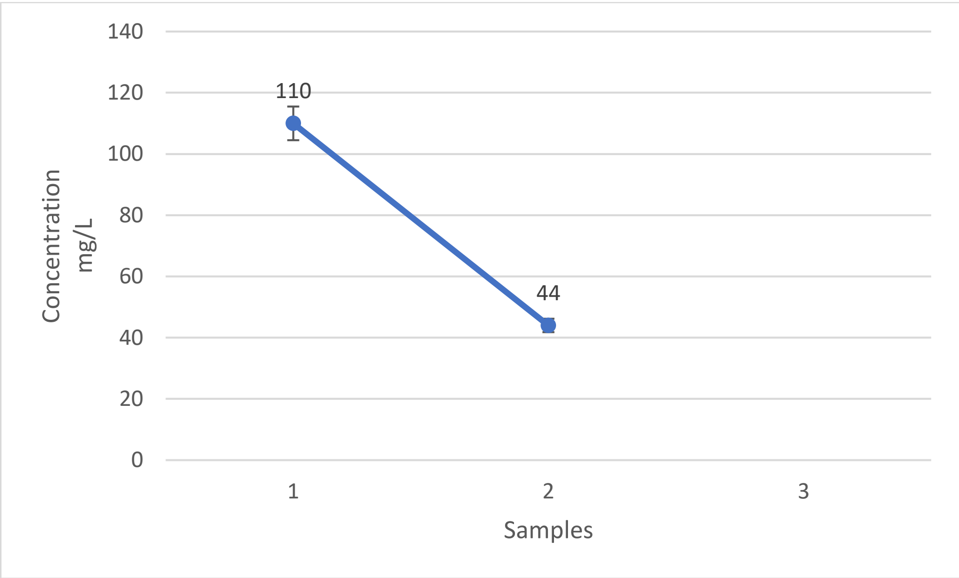


Figure 16: Carbon length at 20cm

As the depth of the filter was increased, the percentage removal also increased. At depth 20cm, the TSS value dropped from 110mg/L to 44mg/L being at a percentage removal of 60%.

At this depth, the surface area of the carbon was increased, active deposition sites also increased which gave the particles in the water more adsorption areas thus decrease in TSS.

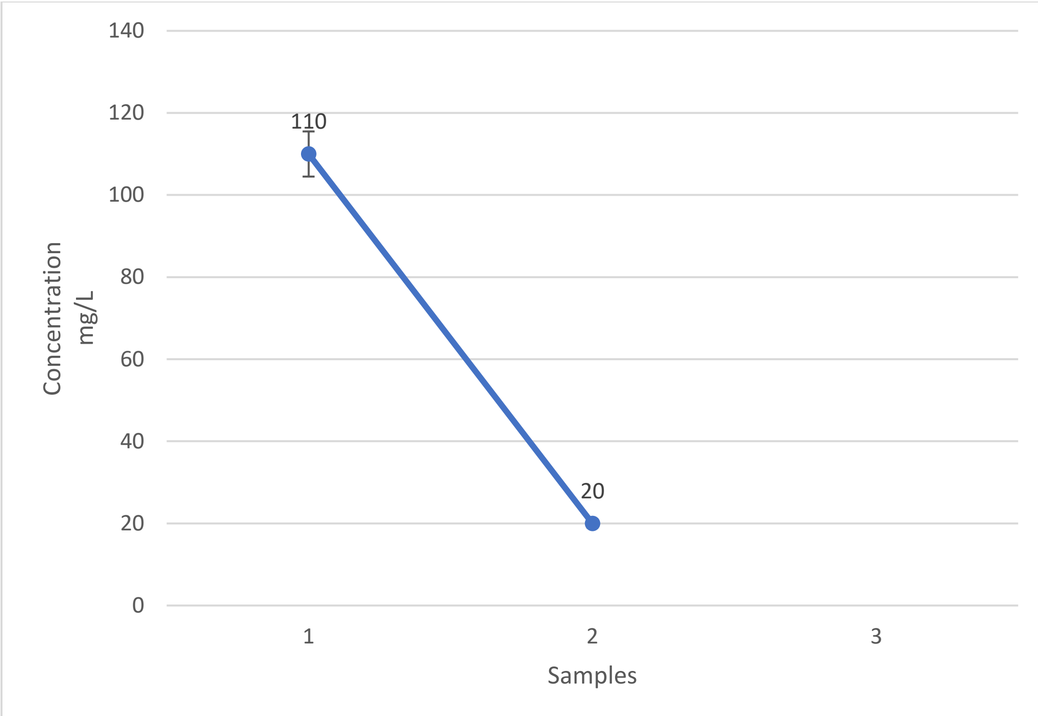


Figure 17: Carbon length at 30cm

At 30cm depth, the percentage was seen greatest at 81% where the concentration dropped from 110mg/L to 20mg/L. At this depth, there is a great force of attraction at the surface of the carbon for the pollutants, the active sites are of great volume and the contact time was also increased hence great reduction of TSS in the effluent.

4.2.3 Orthophosphates.

Table 4: Ortho % percentage reduction with increase in carbon depth.

Parameter	Units	Filter A1	Filter B1	Filter A	Filter B
Initial Ortho-phosphate	mg/L	42	42	40	40
Carbon length	cm	8	12	20	30
Final ortho-phosphates	mg/L	37	22	14	8
Percentage reduction	%	12	47	65	78

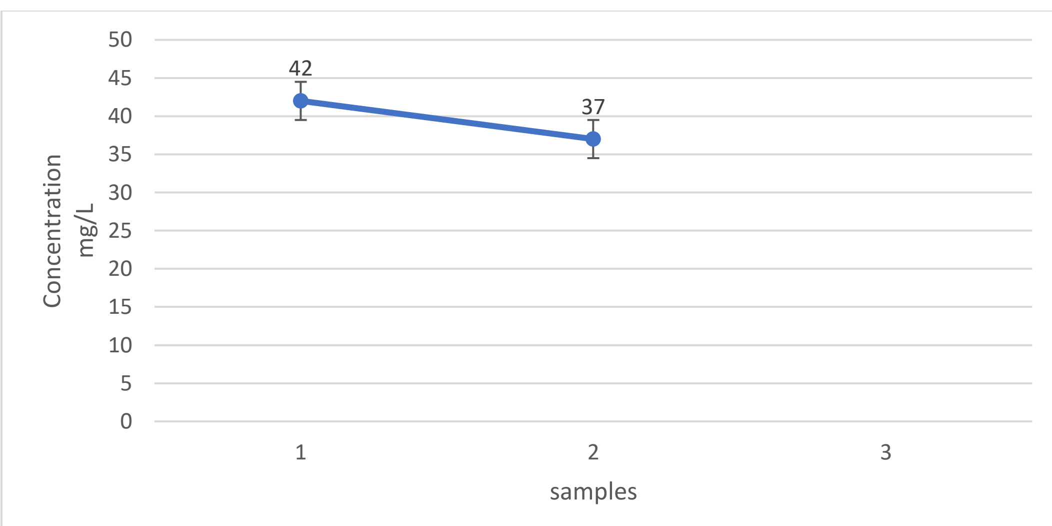


Figure 18: ***Carbon length at 8cm***

At 8cm depth of carbon, there was a percentage reduction of 12% of orthophosphates which showed the initial value of 42mg/L decrease to 37mg/L as per graph.

This concentration was still above the effluent discharge standard of 5mg/L as the depth of carbon had few active deposition sites for the forces to attract the phosphates.

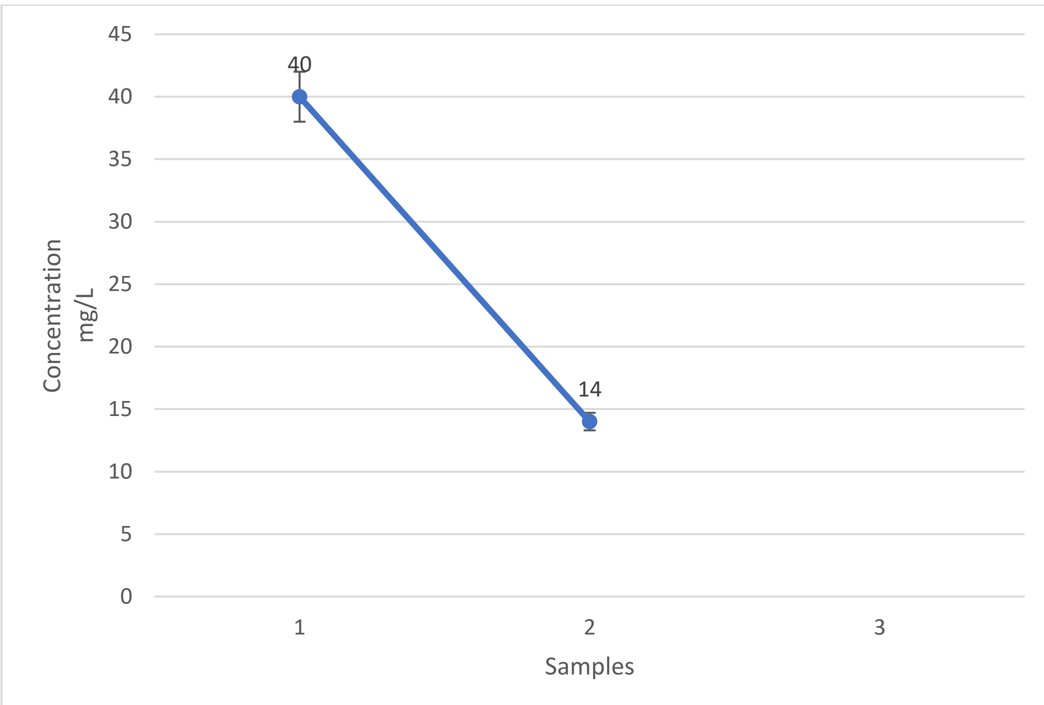


Figure 19: Carbon length at 20cm.

When the depth was increased to 20cm, there was an increase in the active sites available for the phosphates to be attracted to the pores and deposition sites.

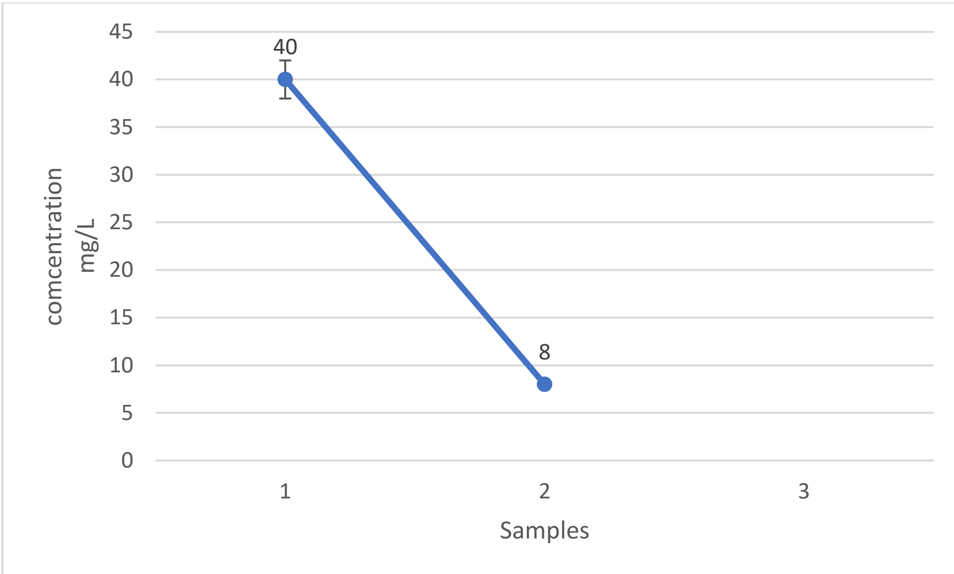
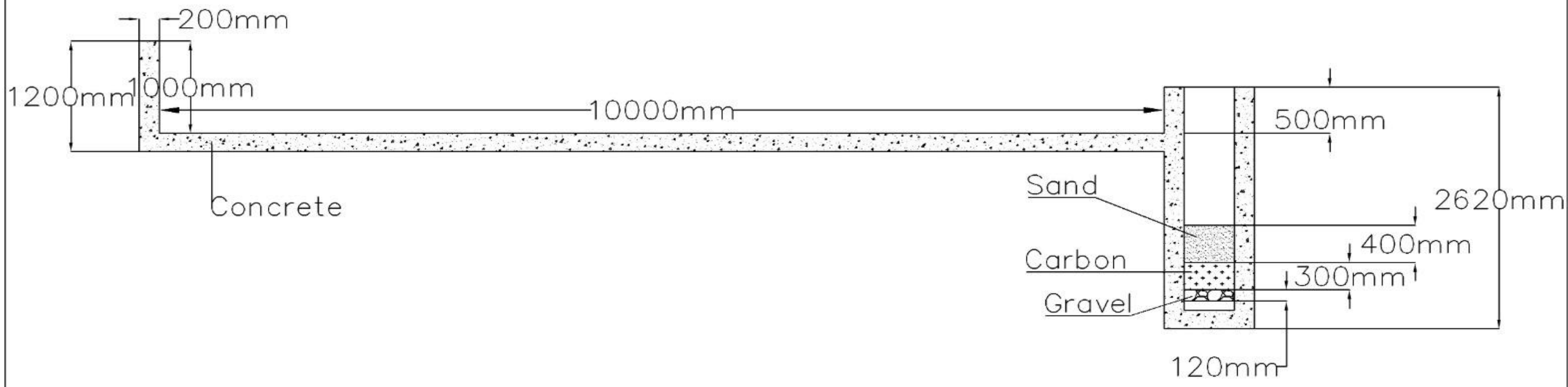


Figure 20: Carbon length at 30cm

At 30cm depth, there was the most effective percentage reduction of orthophosphates from the effluent. The concentration was decreased from 40mg/L to 8mg/L having a 78% removal.

This was due to the increased contact time with the carbon layer for the removal of the pollutant. There was also an increase in the available active sites for the attraction of the orthophosphates to be absorbed on the carbon.



PROJECT: ASSESSING THE USE OF ENHANCED SAND FILTER WITH BAMBOO ACTIVATED GRANULES FOR TERTIARY TREATMENT OF WASTEWATER EFFLUENT
DRAWING TITLE: TERTIARY EFFLUENT TREATMENT SYSTEM
AUTHOR: KAYIIRA JOEL PAUL
REG. NUMBER: M22B32/017

Figure 21 Tertiary effluent treatment system.

CHAPTER 5: CONCLUSION AND RECOMMENDATION.

5.1 Conclusion.

The wastewater effluent BOD was 109mg/L at discharge point and 90.75mg/L downstream which is above 50mg/L as the NEMA standards.

The wastewater effluent TSS was 141mg/L at discharge point and 128mg/L downstream which is above 100mg/L as the NEMA standards.

The wastewater effluent orthophosphate was 41.97mg/L at discharge point and 15.3mg/L downstream which is above 5mg/L as the NEMA standards.

The carbon material was most efficient at depth of 30cm removing upto 38% of BOD, 81% of TSS and 78% of orthophosphates.

Orthophosphates didn't meet the permissible limit but can still be discharged for further treatment in the wetland which acts a maturation pond. This is due to the physical activation process of the bamboo.

5.2 Recommendations.

1. Determine the physical-chemical and bacteriological characteristics.

Recommended that an activated carbon treatment should be added as a tertiary treatment unit to polish and remove the excess concentrations.

2. To determine the percentage removal of pollutants by activated bamboo carbon granules in the media filter.

Further studies should be made on impregnating the carbon with a chemical so as to increase the removal effectiveness especially on TSS removal.

3. To design a tertiary treatment system using the activated bamboo and in the media filter.

Regular maintenance should be adopted so as to monitor the performance of the filter and monitor the BOD and TSS effluent to the wetland.

APPENDICES

NATIONAL WATER & SEWERAGE CORPORATION

HEAD OFFICE

TELEGRAMS WATERS KAMPALA
Telephone : 256 - 313 - 315000/100
Twitter : @nwscug
Facebook : www.facebook.com/waterug
Email : info@nwsc.co.ug

P.O. Box 7053
Plot 3 Nakasero
KAMPALA

Our Ref: BSS/R&D/05-08

Date: 30th August 2025

CHIEF MANAGER, SEWERAGE SERVICES

PLANT MANAGER, LUBIGI SEWAGE TREATMENT PLANT

Re: PERMISSION TO CONDUCT RESEARCH IN NWSC

This is to introduce to you Kayiira Joel, a fourth year student pursuing Bachelor of Science degree in Civil and Environmental Engineering at Uganda Christian University. He has been granted permission to conduct his research in NWSC. The research tittle is:

[illegible]

The student would like to collect wastewater samples from Lubigi and carry out experiments in regard to this study. It is expected that the findings from this research will be made available to NWSC and key recommendations beneficial to the Corporation will be adopted to improve our operations. In this regard, you are kindly requested to provide him with the necessary support to successfully accomplish the research project.

This admission is valid up to end of October, 2025.

Anticipating your usual cooperation.

Susan Namaalwa
For: Manager, Research and Development

"NW&SC - Water is Good Water for Public Health"

NATIONAL WATER AND SEWERAGE CORPORATION

CENTRAL LABORATORY- BUGOLOBI

P.O BOX 7053 KAMPALA Email: waterquality@nwsc.co.ug

Student: Kayiira Joel

Address: Uganda Christian University

Mukono (Uganda)

Date Sample Tested: 03rd November , 2025.

Analysis Laboratory results for waste water sampled on 03rd November 2025.

Before treatment.

Parameter	Unit	Result	Effluent Discharges Standard
Ortho - Phosphates	mg/L	43	5.0
Total suspended solids(TSS)	mg/L	125	100

After treatment

Parameter	Unit	Result		Effluent Discharges Standard
		Filter A	Filter B	
Ortho - Phosphates	mg/L	10.8	8.3	5.0
Total suspended solids(TSS)	mg/L	64	23	100

Remarks: The results for the water samples tested were as above.
Analysed by: Wanyera Julius (QCO) &
Kayiira Joel

04/11/2025

NATIONAL WATER AND SEWERAGE CORPORATION
04 NOV 2025
WATER QUALITY MANAGEMENT DEPT
THE CENTRAL LABORATORY

[illegible]	Lubigi Upstream	1.08	7.56	418	24.3	300	33	31.2	49		2.5	
[illegible]	Lubigi Upstream	2.15	7.6	418	22.2	220	41	21	39		2.9	
[illegible]-19	Lubigi Upstream	0.89	7.69	410	21.4	150	15	28.2	37		1.2	1.8
[illegible]-19	Lubigi Upstream	0.39	7.48	463	22.9	250	49	27.9	36		1.4	
[illegible]-Oct-19	Lubigi Upstream	0.16	7.67	510	24.2	190	35	21.3	34		5.3	
22-Oct-19	Lubigi Upstream	0.78	7.5	545	21.4	210	48	18.3	21		1.6	
05-Nov-19	Lubigi Upstream	2.11	7.58	450	24.5	250	38	18	24		2.7	
12-Nov-19	Lubigi Upstream	1.22	7.54	430	22.2	250	54	44.1			1.9	
19-Nov-19	Lubigi Upstream	0.54	7.7	498	24.1	280	18	49.8			2.5	
26-Nov-19	Lubigi Upstream	2.96	7.62	458	23.8	300	15	21.3			2.3	
03-Dec-19	Lubigi Upstream	2.94	7.6	494	22.8	300	706	159			2.0	
10-Dec-19	Lubigi Upstream	0.13	7.43	504	20.9	250	342	97.2			2.3	
17-Dec-19	Lubigi Upstream	2.43	7.7	497	20.6	220	32	51.9			1.1	
24-Dec-19	Lubigi Upstream	3.5	7.7	482	22.3	150	36				1.3	
07-Jan-20	Lubigi Upstream	0.46	7.77	444	22.9	150	20	26.4	35		1.0	
14-Jan-20	Lubigi Upstream	0.96	7.68	520	24	320	30	33.9	42		2.2	
21-Jan-20	Lubigi Upstream	1.89	7.78	463	21	540	19	24.9	14		2.5	
28-Jan-20	Lubigi Upstream	0.77	7.67	512	19.5		913	107.1	182		4.3	
04-Feb-20	Lubigi Upstream	4.04	7.27	420	21.9	180	113				2.1	
11-Feb-20	Lubigi Upstream	1.24	7.41	548	23.4	260	22	80.1	140		3.2	
18-Feb-20	Lubigi Upstream	2.29	7.57	504	21.9	160	411	51	180		2.1	
25-Feb-20	Lubigi Upstream	1.27	7.71	502	23	240	36	27	32		2.7	
03-Mar-20	Lubigi Upstream	0.62	7.48	591	25.2	180	32	42.3			2.6	
10-Mar-20	Lubigi Upstream	2.98	7.6	559	22.4	240	54	27	39		1.3	
17-Mar-20	Lubigi Upstream	2.14	7.52	420	23.7	300	31	84.3			3.2	
24-Mar-20	Lubigi Upstream	2.25	7.62	450	24.1	200	43	89.4	117		2.0	
07-Apr-20	Lubigi Upstream	4.24	8.32	486	27.1	210	42	34.5	44		0.7	
14-Apr-20	Lubigi Upstream	2.94	7.71	420	24.9	240	51	34.8	48		1.5	
21-Apr-20	Lubigi Upstream	2.27	7.6	459	23.5	210	83	78	93		0.2	
28-Apr-20	Lubigi Upstream	3.66	7.31	488	23.5	230	49	66.9	92		1.3	
05-May-20	Lubigi Upstream	3.26	7.61	426	24.1	240	28	16.1	29		3.6	
12-May-20	Lubigi Upstream	4.61	7.64	437	24.6	220	32	25	39		1.7	
19-May-20	Lubigi Upstream	4.26	7.62	283	23.5	130	698	122.1	202		2.7	
26-May-20	Lubigi Upstream	5.19	7.56	479	22.7	240	23	24.3	36		2.0	

Date	Sample Description	Dissolve	pH	Conduct	Temp (°C	Total Alkalinity (mg/L as CaCO3)	Total Suspend Solids (mg/L)	BOD5 (mg	COD (mg	Ammonia	Phosphate (ortho) (mg/L)	Phosphate (Total) (mg/L)	Total Nitrogen(mg/L)
04-Jul-17	Lubigi Downstream	2.85		733	19.6	280	26	21		49.0	0.6	2.4	
11-Jul-17	Lubigi Downstream	2.33		778	21.8	270	18	25			2.2	2.9	
18-Jul-17	Lubigi Downstream	2.21		766	20.5	290	24	23			1.7	2.2	
25-Jul-17	Lubigi Downstream	3.76		836	21.6	350	46	25					
01-Aug-17	Lubigi Downstream	1.94		823	22.8	300	38	35			1.0	3.1	
08-Aug-17	Lubigi Downstream	2.17	7.5	998	20.7	480	90	34					
15-Aug-17	Lubigi Downstream	2.22	7.3	851	21.9	340	50	36			2.9	3.4	
22-Aug-17	Lubigi Downstream	2.61	7.2	817	21.6	360	40	30			4.1	4.4	
05-Sep-17	Lubigi Downstream	4.07	7.5	610	20.4	280	92	11			1.5	1.9	
12-Sep-17	Lubigi Downstream	2.64	7.3	734	22.1	310	40	14					
19-Sep-17	Lubigi Downstream	2.65	6.9	764	21	290	50				3.1	5.3	
26-Sep-17	Lubigi Downstream	3.83	7.3	470	20.8	160	242	11			1.0	1.5	
03-Oct-17	Lubigi Downstream	1.06	7.7	796	21.3	270	41				4.5	5.0	
10-Oct-17	Lubigi Downstream	2.9	7.3	738	21.5	310	36	18			12.5	13.5	
17-Oct-17	Lubigi Downstream	1.51	7.3	730	23.8	280	82	28			1.0	1.2	
24-Oct-17	Lubigi Downstream	2.12	7.2	616	23.1	240	144	5			2.7	3.9	
07-Nov-17	Lubigi Downstream	2.86	7.3	551	21.8	130	160	14			0.9	1.4	
14-Nov-17	Lubigi Downstream	2.45	7.5	746	22.9	140	132	216			1.0	1.0	
21-Nov-17	Lubigi Downstream	1.84	7.6	982	29.8	330	113	60.3			14.0	15.2	
28-Nov-17	Lubigi Downstream	2.08	7.7	745	23.9	180	46	20			2.8	3.2	
05-Dec-17	Lubigi Downstream	1.94	7.5	791	22.5	300	50	21			4.6	6.0	
12-Dec-17	Lubigi Downstream	2.01	7.4	1155	21.6	170	54	30			4.6	6.4	
19-Dec-17	Lubigi Downstream	1.61	7.37	730	21.8	100	45	29			6.3		
26-Dec-17	Lubigi Downstream	5.65	7.79	726	23.8		43	23			4.3		
02-Jan-18	Lubigi Downstream	0.97	7.43	675	20.9	124	69	23.4			3.3		
09-Jan-18	Lubigi Downstream	2.26	7.37	624	20.9	130	48	49			3.7		
16-Jan-18	Lubigi Downstream	0.87	7.39	677	23.8	120	36	31			2.7		
23-Jan-18	Lubigi Downstream	2.91	7.23	661	23.8	200	78	47			2.7		
06-Feb-18	Lubigi Downstream	1.13	7.49	709	22.9	270	60	34			6.5		
13-Feb-18	Lubigi Downstream	1.5	7.47	626	23.2		54	28			8.1		

	Sample Name	DO (mg/L)	pH	EC (µS/cm	T (°C)	TSS (mg/L)	BOD5 (mg	COD (mg/	Ammonia (mg/L)	Phosphate (ortho) (mg/L)	Phosphate (Total) (mg/L)
04-Jul-23	Lubigi Downstream	0.24	8.21	610	24.3	120	58	166		11.2	
11-Jul-23	Lubigi Downstream	0.24	8.30	558	26.0	89	49	56		6.5	
18-Jul-23	Lubigi Downstream	0.09	8.15	673	28.0	104	68	149		11.1	
25-Jul-23	Lubigi Downstream	0.08	8.06	604	25.0	240	73	316		5.5	
01-Aug-23	Lubigi Downstream	0.06	8.03	530	26.4	250	93	165		5.9	
08-Aug-23	Lubigi Downstream	0.09	8.00	646	24.6	683	87	395		6.2	
15-Aug-23	Lubigi Downstream	0.04	7.98	804	26.9	504	60			13.9	
22-Aug-23	Lubigi Downstream	0.06	7.90	588	27.8	704	52			7.6	
05-Sep-23	Lubigi Downstream	0.04	7.90	594	26.0	204	59			5.6	
12-Sep-23	Lubigi Downstream	0.04	7.96	628	27.2	104	60			4.5	
19-Sep-23	Lubigi Downstream	0.04	7.96	598	27.1	90	53			2.1	
26-Sep-23	Lubigi Downstream	0.05	7.92	592	26.3	56	55			6.1	
03-Oct-23	Lubigi Downstream	0.05	8.08	814	28.3	96	55	189		14.9	
10-Oct-23	Lubigi Downstream	0.04	8.00	610	27.7	104	39			4.0	
17-Oct-23	Lubigi Downstream	0.05	8.01	655	26.3	89	34			3.3	
24-Oct-23	Lubigi Downstream	0.05	8.10	644	29.2	54	52			5.4	
07-Nov-23	Lubigi Downstream	0.05	8.04	680	26.0	90	40			4.3	
14-Nov-23	Lubigi Downstream	0.08	7.96	674	24.3	80	54	209		10.1	
21-Nov-23	Lubigi Downstream	0.03	8.12	688	24.2	907	50	104		3.1	
28-Nov-23	Lubigi Downstream	0.04	8.24	730	26.0	104	59			11.2	
05-Dec-23	Lubigi Downstream	0.11	8.04	646	24.1	1041	56	110		1.8	
12-Dec-23	Lubigi Downstream	0.09	7.94	674	26.0	66	39	100		3.7	
19-Dec-23	Lubigi Downstream	0.07	8.01	714	26.0	78	55	104		10.1	
26-Dec-23	Lubigi Downstream	0.04	8.03	788	26.0	48	113	120		9.6	
02-Jan-24	Lubigi Downstream	2.68	8.04	664	25.0	78	59	112		10.1	
09-Jan-24	Lubigi Downstream	0.04	7.98	676	25.4	143	106	112		10.1	
16-Jan-24	Lubigi Downstream	0.08	8.01	667	25.8	106	51	104		11.7	
23-Jan-24	Lubigi Downstream	0.03	8.02	788	25.6	173	74	185		10.5	
06-Feb-24	Lubigi Downstream	0.04	7.08	884	26.2	70	67	119		12.1	

13-Feb-24	Lubigi Downstream	0.05	7.92	796	25.2	86	39	100		8.3	
20-Feb-24	Lubigi Downstream	0.03	7.92	788	26.2	104	55	104		10.8	
27-Feb-24	Lubigi Downstream	0.04	8.24	730	26.0	104	113	120		11.2	
05-Mar-24	Lubigi Downstream	0.08	7.70	735	28.5	66	39	100		11.3	
12-Mar-24	Lubigi Downstream	0.95	7.67	768	27.3	104	87	119		6.2	
19-Mar-24	Lubigi Downstream	0.04	8.15	673	28.2	83	68	95		11.1	
26-Mar-24	Lubigi Downstream	0.05	7.92	592	27.3	56	55	101		6.1	
04-Apr-24	Lubigi Downstream	0.05	7.88	767	28.6	111	106	130		28.1	
09-Apr-24	Lubigi Downstream	0.03	7.92	788	26.2	104	55	104		10.8	
16-Apr-24	Lubigi Downstream	0.04	7.96	598	27.1	90	53	395		2.1	
23-Apr-24	Lubigi Downstream	0.08	8.06	604	25.0	240	73	316		5.5	
07-May-24	Lubigi Downstream	0.95	7.67	801	27.4	124	87	176		6.2	
14-May-24	Lubigi Downstream	0.09	7.40	774	26.2	75	53	86		130.1	
21-May-24	Lubigi Downstream	0.04	8.12	680	24.2	917	367	897		3.1	
27-May-24	Lubigi Downstream	0.32	7.84	660	27.4	64	35	75		10.1	
04-Jun-24	Lubigi Downstream	0.13	8.04	751	24.4	1390	1970	71		8.9	
11-Jun-24	Lubigi Downstream	0.04	7.98	676	25.4	143	106	112		10.1	
18-Jun-24	Lubigi Downstream	0.04	8.01	667	25.8	106	19	72		12.7	
25-Jun-24	Lubigi Downstream	0.06	8.08	787	26.0	107	113	165		10.6	
02-Jul-24	Lubigi Downstream	0.14	7.90	129	22.6	53		110		46.0	
09-Jul-24	Lubigi Downstream	0.09	7.98	676	25.4	179	106	124		11.4	
16-Jul-24	Lubigi Downstream	3.67	7.26	467	17.6	29	43	92		2.7	
23-Jul-24	Lubigi Downstream	0.04	8.04	6200	24.7	26	36	41		2.5	
06-Aug-24	Lubigi Downstream	0.05	7.92	592	26.3	142	62	55		16.3	
13-Aug-24	Lubigi Downstream	0.05	8.10	644	29.2	54	44	67		5.4	
20-Aug-24	Lubigi Downstream	0.09	7.77	773	20.4	71	106	124		11.9	
27-Aug-24	Lubigi Downstream	0.06	8.08	787	26.0	107	113	165		10.6	
03-Sep-24	Lubigi Downstream	0.06	8.08	787	26.0	107	113	165		10.6	
10-Sep-24	Lubigi Downstream	0.08	7.92	129	26.0	194	120	158		8.9	
17-Sep-24	Lubigi Downstream	0.24	8.12	688	24.2	198	50	104		3.1	
24-Sep-24	Lubigi Downstream	0.11	8.04	646	24.1	104	56	110		1.8	
01-Oct-24	Lubigi Downstream	0.05	8.04	814	23.3	96	67	189	9.1	8.1	9.1
08-Oct-24	Lubigi Downstream	0.04	7.56	635	22.5	51	44	78		9.3	11.2

03-Dec-24	Lubigi Final	0.56	7.85	3210	25.7	219	89	179		46.1	48.5
11-Dec-24	Lubigi Final	1.04	8.45	2910	24.8	225	100	246		33.2	37.3
17-Dec-24	Lubigi Final	2.31	8.50	1117	22.1	95	50	100		48.4	50.4
24-Dec-24	Lubigi Final	0.44	8.45	1500	21.5	100	47	109		49.1	53.5
07-Jan-25	Lubigi Final	0.48	8.24	2200	24.3	210	185	164		38.9	41.5
14-Jan-25	Lubigi Final	0.52	8.24	2100	24.2	128	120	180		40.1	43.5
21-Jan-25	Lubigi Final	0.03	8.15	2040	24.0	221	110	120		39.1	41.1
28-Jan-25	Lubigi Final	0.48	8.24	1950	24.2	150	110	230		40.1	42.5
02/04/2025	Lubigi Final	0.40	7.99	2900	23.4	300	112	362		41.4	44.3
02/11/2025	Lubigi Final	0.48	7.92	2650	23.2	286	122	208		41.4	45.4
18/2/2025	Lubigi Final	0.34	7.95	3800	27.1	316	249	504		45.0	47.3
25/2/2025	Lubigi Final	0.54	7.98	3200	27	371	235	318		40.1	43.3
04/01/2025	Lubigi Final	0.46	8.14	2650	24.1	188	98	141	30	40.1	42.6
04/08/2025	Lubigi Final	0.55	8.14	2890	24.2	146	100	136	20	42.1	
15/4/2025	Lubigi Final	0.42	8.24	2800	23.0	198	92	171	27	40.2	
22/4/2025	Lubigi Final	0.50	8.02	2700	24.1	179	100	167	30	46.6	48.3
05/05/2025	Lubigi Final	7.13	7.99	1185	26.4	100	50	105		30.7	33.7
13/5/2025	Lubigi Final	6.31	7.32	1020	24.2	97	43	90		29.4	31.1
20/5/2025	Lubigi Final	3.98	8.04	3800	27.1	79	33.3	96		43.7	48.4
27/5/2025	Lubigi Final	3.05	7.98	1190	27	89	32	93		41.3	45.3
04/06/2025	Lubigi Final	2.03	7.99	2900	23.4	98	45	98	27.4	41.4	44.3
10/06/2025	Lubigi Final	2.06	7.92	2650	23.2	95	50	100	30	41.4	45.4
17/06/2025	Lubigi Final	1.97	7.95	3800	27.1	178	48	99	41	45.0	47.3
24/06/2025	Lubigi Final	1.36	7.98	3200	27	96	79	93	30.9	40.1	43.3
01/07/2025	Lubigi Final	7.13	7.99	1185	26.4	100	50	105	37.3	30.7	33.7
08/07/2025	Lubigi Final	6.31	7.32	1020	24.2	97	43	90	33.6	29.4	31.1
15/07/2025	Lubigi Final	0.28	8.04	1800	25.5	97	50	98	38.42	41.2	44.8
22/07/2025	Lubigi Final	0.44	8.01	2400	24.4	270	212	426	42.09	40.4	43.3
08/02/2025	Lubigi Final	3.54	7.84	1601	25.1	141	108	98		41.9	

NATIONAL WATER AND SEWERAGE CORPORATION

CENTRAL LABORATORY- BUGOLOBI

P.O BOX 7053 KAMPALA Email: waterquality@nwsc.co.ug

Student: Kayiira Joel

Address: Uganda Christian University

Mukono (Uganda)

Date Sample Tested: 20 th October , 2025.

Analysis Laboratory results for waste water sampled on 20th October 2025.

Before treatment.

Parameter	Unit	Result	Effluent Discharges Standard
Ortho - Phosphates	mg/L	40	5.0
Total suspended solids(TSS)	mg/L	110	100

After treatment

Parameter	Unit	Result		Effluent Discharges Standard
		Filter A	Filter B	
Ortho - Phosphates	mg/L	14	8	5.0
Total suspended solids(TSS)	mg/L	44	20	100

Remarks: The results for the water samples tested were as above.
Analysed by: Wanyera Julius (QCO) & Kayiira Joel 21/10/2025

NATIONAL WATER AND SEWERAGE CORPORATION
21 OCT 2025
WATER QUALITY MANAGEMENT DEPT
THE CENTRAL LABORATORY

NATIONAL WATER AND SEWERAGE CORPORATION

CENTRAL LABORATORY- BUGOLOBI

P.O BOX 7053 KAMPALA Email: waterquality@nwsc.co.ug

Student: Kayiira Joel

Address: Uganda Christian University

Mukono (Uganda)

Date Sample Tested: 10[th] November , 2025.

Analysis Laboratory results for waste water sampled on 10th November, 2025.

Before treatment.

Parameter	Unit	Result	Effluent Discharges Standard
Ortho - Phosphates	mg/L	42	5.0
Total suspended solids(TSS)	mg/L	138	100

After treatment

Parameter	Unit	Result		Effluent Discharges Standard
		Filter A	Filter B	
Ortho - Phosphates	mg/L	37	22	5.0
Total suspended solids(TSS)	mg/L	126	84	100

Remarks: The results for the water samples tested were as above.
Analysed by: Wanyera Julius (QCO) & 10/11/2025
Kayiira Joel

NATIONAL WATER AND SEWERAGE CORPORATION
10 NOV 2025
WATER QUALITY MANAGEMENT DEPT
THE CENTRAL LABORATORY

Research Coordinator's Name: R Cauchux .... Signature: ....

Session	Chapter Reviewed	Date &Time	Duration of Session	Signatures		Progress Rating
6.	Problem identification	25/08/2025	2hrs.			15

Research Coordinator's Name: .... Signature: ....

7.	Secondary data review	8/09/2025	1hr. 30mins			
8.	Secondary data review.	8/09/2025	1hr. 30mins.			

Research Coordinator's Name: .... Signature: ....

9.	Report -writeup review	29/09/2025	40mins			
10.	Report - writeup review.	29/09/2025				

Research Coordinator's Name: .... Signature: ....

Session	Chapter Reviewed	Date &Time	Duration of Session	Signatures		Progress Rating
				Student	*Supervisor*	
11.	Checking of result	24/11/25	40mins.			
12.						

Research Coordinator's Name: .... Signature: ....

13.	Report review	24/11/2025	40mins			
14.						

UGANDA CHRISTIAN UNIVERSITY

Faculty of Engineering, Design, & Technology
Department of Engineering & Environment

"A Centre of Excellence in the Heart of Africa"

FINAL YEAR RESEARCH AND DESIGN PROJECT
REGULAR SUPERVISION REPORT

Supervisor's Name: Rodgers Taylor

Student's Name (01): DUKU NELSON Reg. No: M22B32/053

Student's Name (02): KAYIIRA JOEL Reg. No: M22B32/017

Proposal Approval Date________ Return Date from Data Collection ________

Session	Chapter Reviewed	Date &Time	Duration of Session	Signatures		Progress Rating
Research Coordinator's Name: R.Taylor			Signature: [signature]			
				Student	Supervisor	
1.	Review of proposal	25/06/2025	1hr	[signature]	[signature]	1.5
2.	Review of proposal	25/06/2025	1hr	[signature]		
Research Coordinator's Name: R.Taylor			Signature: [signature]			
3.	Finding of scope	15/07/2025	30mins	[signature]	[signature]	1.5
4.	Finding of scope	15/07/2025	30mins	[signature]		
Research Coordinator's Name:			Signature:			
5.	Problem identification	25/08/2025	2hrs	[signature]		

NATIONAL WATER AND SEWERAGE CORPORATION

CENTRAL LABORATORY- BUGOLOBI

P.O BOX 7053 KAMPALA Email: waterquality@nwsc.co.ug

Student: Kayiira Joel

Address: Uganda Christian University

Mukono (Uganda)

Date Sample Tested: 10 th November , 2025.

Analysis Laboratory results for waste water sampled on 10th November, 2025.

Before treatment.

Parameter	**Unit**	**Result**	**Effluent Discharges Standard**
Ortho - Phosphates	mg/L	42	5.0
Total suspended solids(TSS)	mg/L	138	100
Biological Oxygen Demand (BOD)	mg/L	85	50

After treatment

Parameter	**Unit**	**Result**		**Effluent Discharges Standard**
		Filter A	**Filter B**	
Ortho - Phosphates	mg/L	37	22	5.0
Total suspended solids(TSS)	mg/L	126	84	100
Biological Oxygen Demand (BOD)	mg/L	53.5	51	50

Remarks: The results for the water samples tested were as above.
Analysed by: Wanyera Julius (QCO) &
Kayiira Joel

NATIONAL WATER AND SEWERAGE CORPORATION

CENTRAL LABORATORY- BUGOLOBI

P.O BOX 7053 KAMPALA Email: waterquality@nwsc.co.ug

Student: Kayiira Joel

Address: Uganda Christian University

Mukono (Uganda)

Date Sample Tested: 03rd November , 2025.

Analysis Laboratory results for waste water sampled on 03rd November 2025.

Before treatment.

Parameter	Unit	Result	Effluent Discharges Standard
Ortho - Phosphates	mg/L	43	5.0
Total suspended solids(TSS)	mg/L	125	100
Biological Oxygen Demand (BOD)	mg/L	95	50

After treatment

Parameter	Unit	Result		Effluent Discharges Standard
		Filter A	Filter B	
Ortho - Phosphates	mg/L	10.8	8.3	5.0
Total suspended solids(TSS)	mg/L	64	23	100
Biological Oxygen Demand (BOD)	mg/L	64	52	50

Remarks: The results for the water samples tested were as above.
Analysed by: Wanyera Julius (QCO) &
Kayiira Joel

NATIONAL WATER AND SEWERAGE CORPORATION

CENTRAL LABORATORY- BUGOLOBI

P.O BOX 7053 KAMPALA Email: waterquality@nwsc.co.ug

Student: Kayiira Joel

Address: Uganda Christian University

Mukono (Uganda)

Date Sample Tested: 20 th October , 2025.

Analysis Laboratory results for waste water sampled on 20th October 2025.

Before treatment.

Parameter	Unit	Result	Effluent Discharges Standard
Ortho - Phosphates	mg/L	40	5.0
Total suspended solids(TSS)	mg/L	110	100
Biological Oxygen Demand (BOD)	mg/L	100	50

After treatment

Parameter	Unit	Result		Effluent Discharges Standard
		Filter A	Filter B	
Ortho - Phosphates	mg/L	14	8	5.0
Total suspended solids(TSS)	mg/L	44	20	100
Biological Oxygen Demand (BOD)	mg/L	68	66	50

Remarks: The results for the water samples tested were as above.
Analysed by: Wanyera Julius (QCO) &
Kayiira Joel

Multi-media			
Anthracite (top layer of quad-media filter, ρ = 1.60)			
Depth	mm	240–600	480
Effective size	mm	1.3–2.0	1.6
Uniformity coefficient	unitless	1.3–1.6	≤1.5
Anthracite (second layer of quad-media filter, ρ = 1.60)			
Depth	mm	120–480	240
Effective size	mm	1.0–1.6	1.1
Uniformity coefficient	unitless	1.5–1.8	1.5
Anthracite (top layer of tri-media filter, ρ = 1.60)			
Depth	mm	240–600	480
Effective size	mm	1.0–2.0	1.4
Uniformity coefficient	unitless	1.4–1.8	≤1.5
Sand (ρ = 2.65)			
Depth	mm	240–480	300
Effective size	mm	0.4–0.8	0.5
Uniformity coefficient	unitless	1.3–1.8	≤1.5
Garnet (ρ = 4.2)			
Depth	mm	50–150	100
Effective size	mm	0.2–0.6	0.35
Uniformity coefficient	unitless	1.5–1.8	≤1.5
Filtration rate	$m^3/m^2\cdot min$	0.08–0.40	0.20

[a] Adapted from Tchobanoglous (1988) and Tchobanoglous et al. (2003).

[b] Anthracite, sand, and garnet sizes selected to limit the degree of intermixing. Use Eq. (11–28) for other values of density, ρ.

Note: $m^3/m^2\cdot min \times 24.5424 = gal/ft^2\cdot min$.

References.

Anderson, J. (2023). *Carbonization processes and mechanisms*.

Bassan, M., Tchobanoglous, G., & Dodane, P. (2014). *Co-treatment of fecal sludge in wastewater stabilization ponds*.

Campbell, C. (2021). *Total Suspended Solids (TSS) and water quality*.

Filippelli, G. (2009). *Phosphorus cycle and environmental impacts*.

Ghaedi, M. (2021). *Adsorbent properties in wastewater treatment*.

Goldberg, S. (2013). *Adsorption processes in environmental systems*.

Hoffmann, H., Platzer, C., & Winker, M. (2010). *Constructed Wetlands for wastewater treatment*.

Kone, D., & Peter, K. (2010). *Waste stabilization pond performance principles*.

Oram, B. (2009). *Phosphorus forms in wastewater*.

PureTech. (2025). *UV and chlorine disinfection techniques*.

Quiroga, P. (2005). *Design of maturation ponds*.

Ramseur, J. (2018). *Municipal wastewater discharge and U.S. water quality*.

Tayler, K. (2018). *Wastewater pond geometry and hydraulic design*.

Tchobanoglous, G., Burton, F., & Stensel, H. (2003). *Wastewater engineering: Treatment and reuse*.

United Nations. (2015). *Sustainable Development Goals*.

Varon, M., et al. (2004). *Nutrient and pathogen removal in maturation ponds*.

WHO. (1987). *Wastewater stabilization pond design manual*

Anderson, J. (2023). *Carbonization processes and mechanisms in biomass conversion*.

Ghaedi, M. (2021). *Adsorbent properties and efficiency in wastewater pollutant removal*.

Goldberg, S. (2013). *Adsorption processes in environmental remediation*.

Hoffmann, H., Platzer, C., & Winker, M. (2010). *Constructed wetlands for wastewater treatment: Fundamentals and applications*.

Nnaji, C., Egbuna, C., & Uche, C. (2018). *Nano-adsorbents in wastewater treatment: Efficiency and recyclability*.

Tchobanoglous, G., Burton, F., & Stensel, H. (2003). *Wastewater engineering: Treatment and reuse*. McGraw-Hill

Rout, R., & Jena, M. (2022). Graphene-based materials for effective adsorption of organic and inorganic pollutants: A critical and comprehensive review. *The Science of the Total Environment, 863*, 160871